



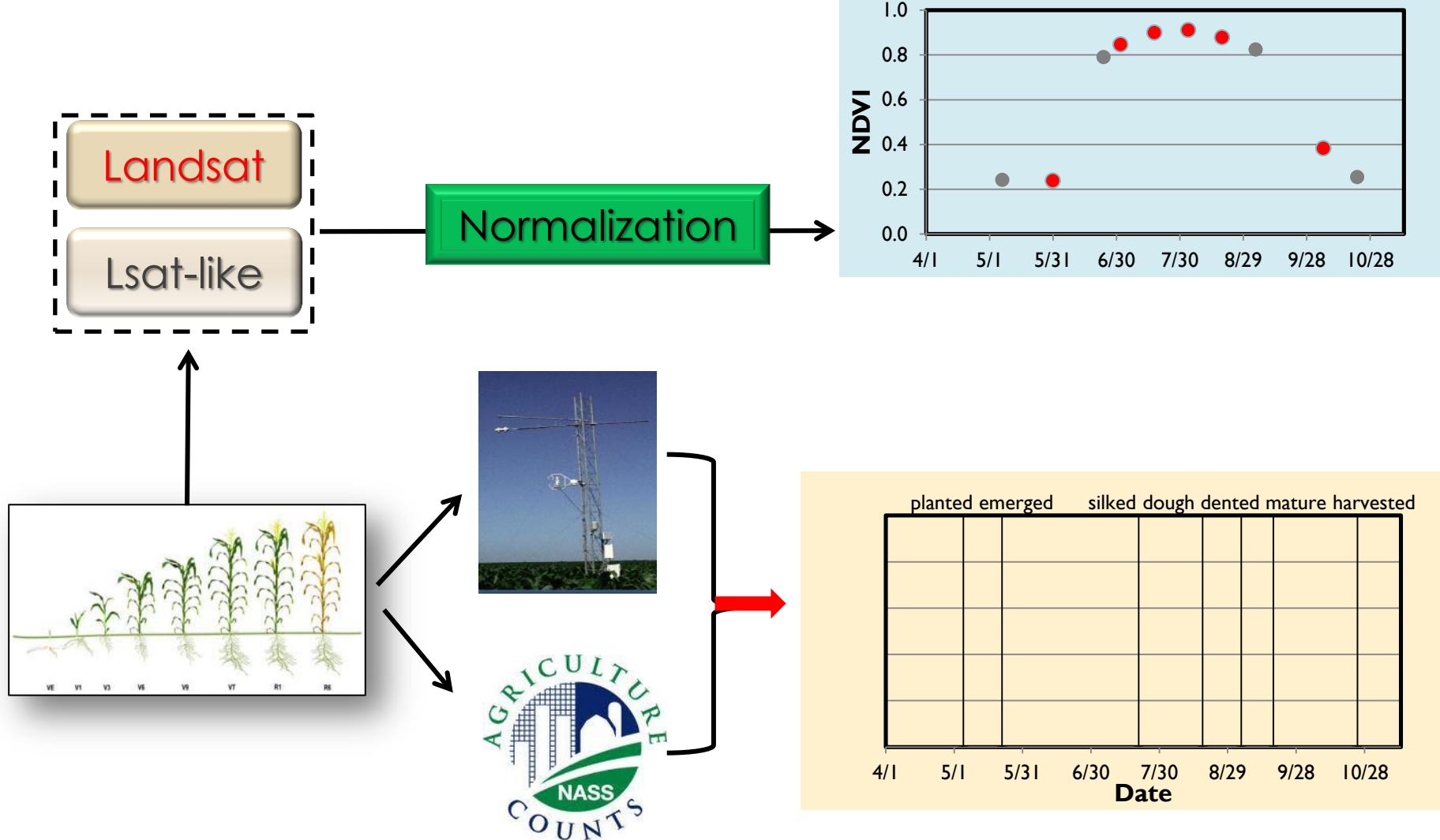
# **Mapping Crop Progress and Yield at 30m Resolution**

**Feng Gao, Martha Anderson, Liang Sun**

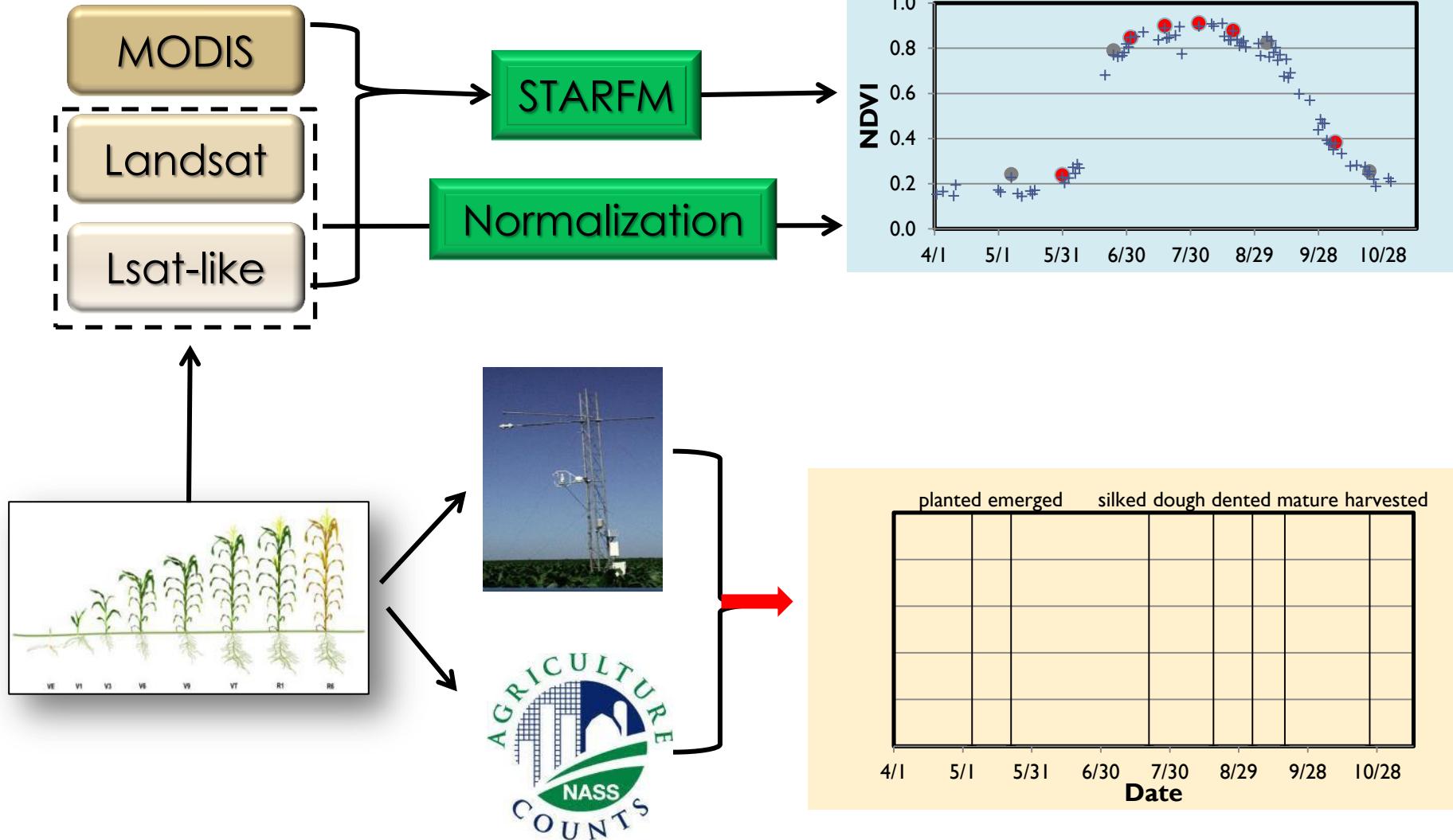
*USDA-Agricultural Research Service  
Hydrology and Remote Sensing Laboratory  
Beltsville, MD*

*USDA is an equal opportunity provider and employer*

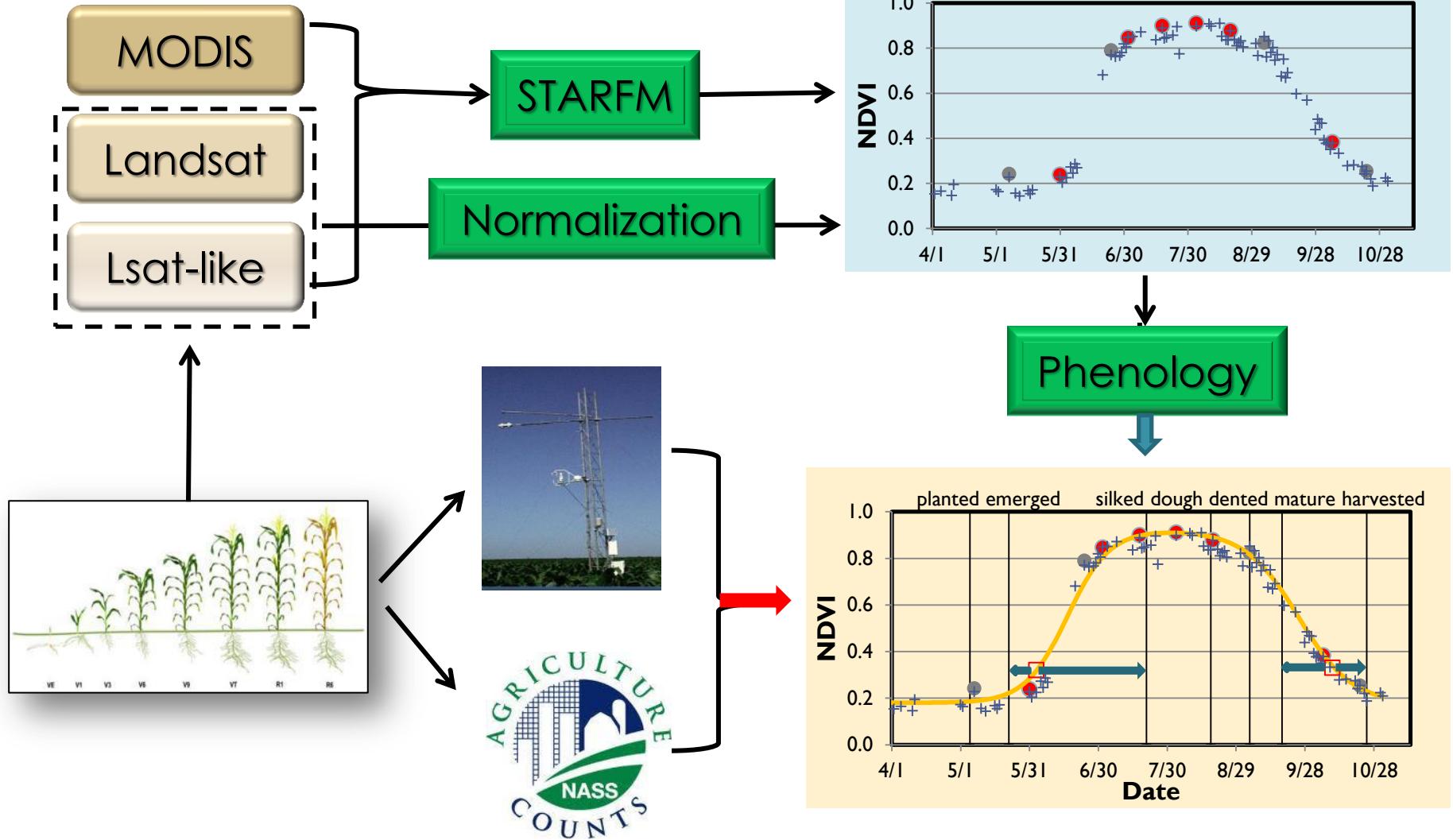
# Mapping Crop Growth Stages using Landsat & MODIS



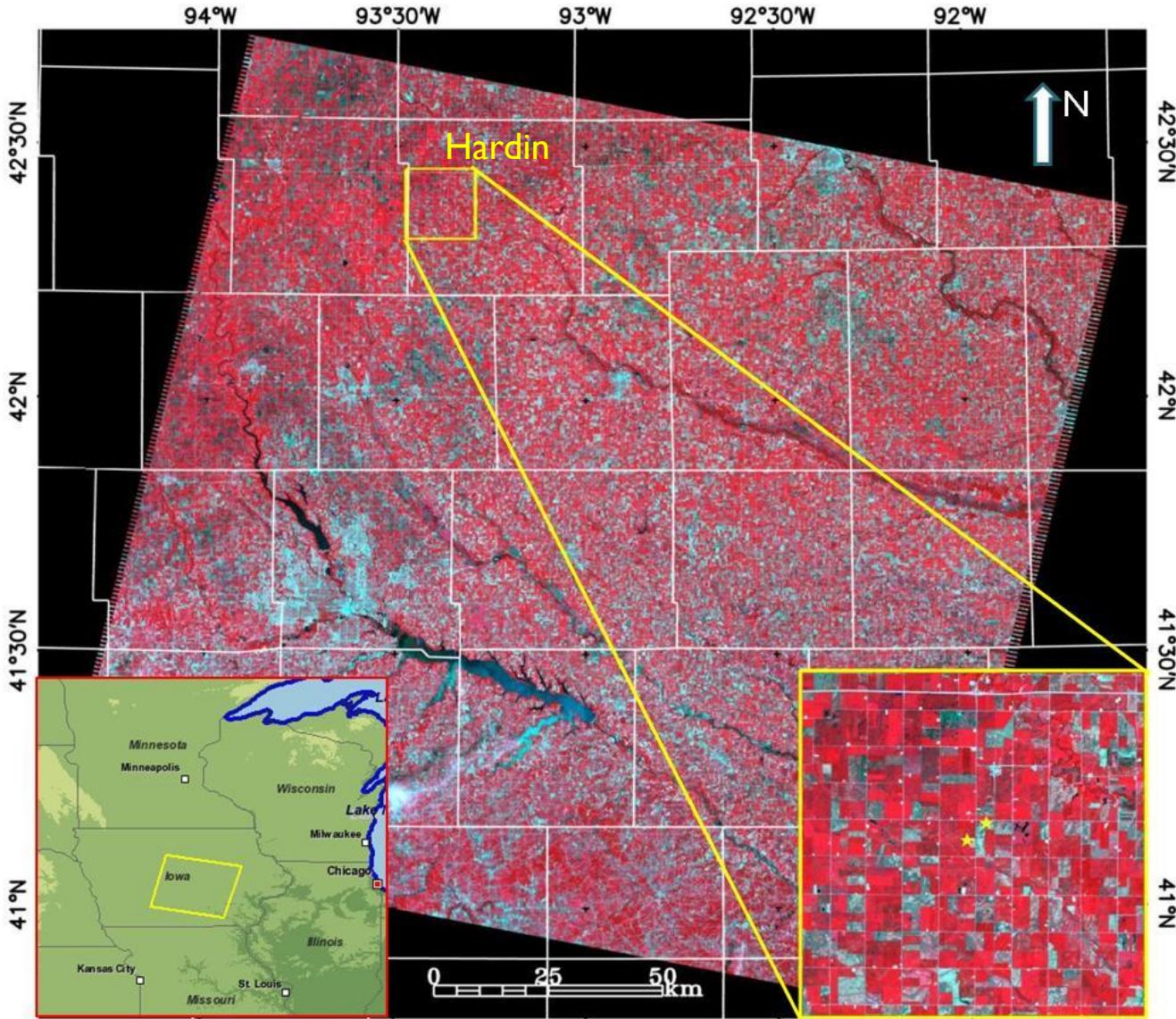
# Mapping Crop Growth Stages using Landsat & MODIS



# Mapping Crop Growth Stages using Landsat & MODIS

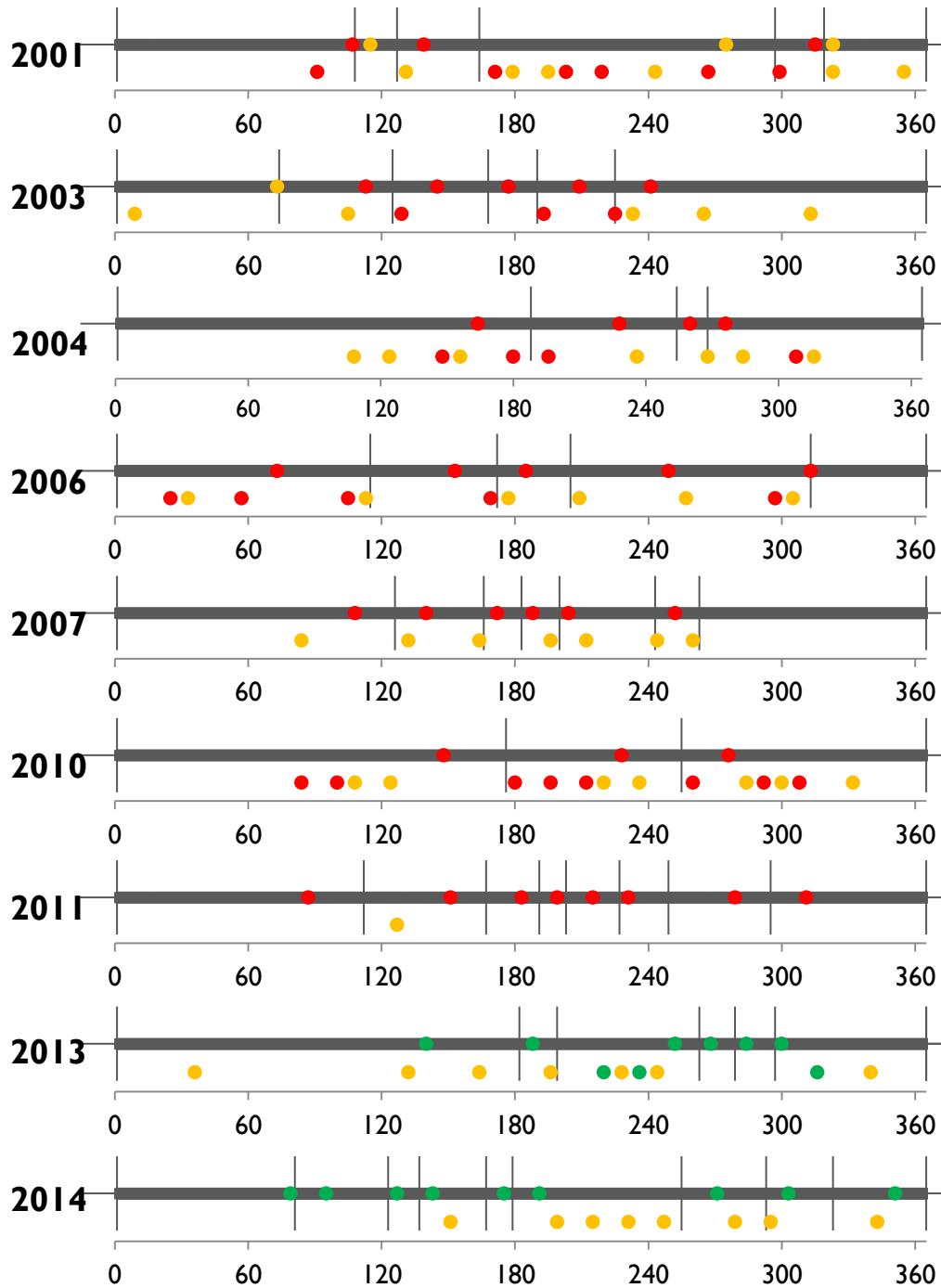


# Study Area I: central Iowa (~20 counties)



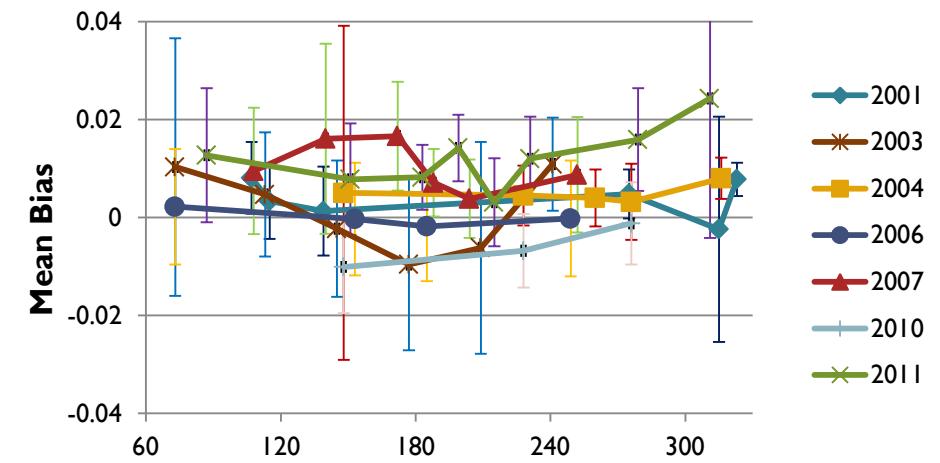
Fourteen years (2001-2014) of Landsat TM, ETM+ and OLI (p26r31) and MODIS (h10v04 and h11v04) were fused to generate daily Landsat-MODIS surface reflectance at 30m resolution using STARFM

# Mapping Crop Progress and Yield at 30m Resolution

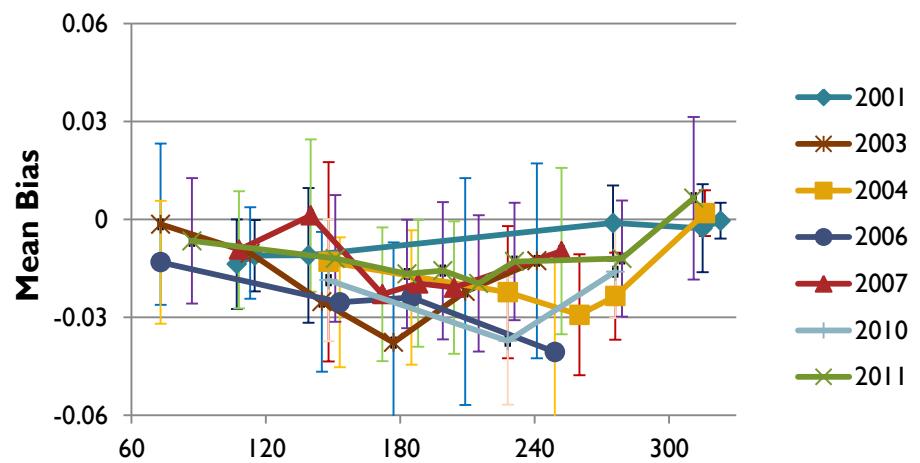


**Landsat and MODIS  
Pair Images  
For Data Fusion**

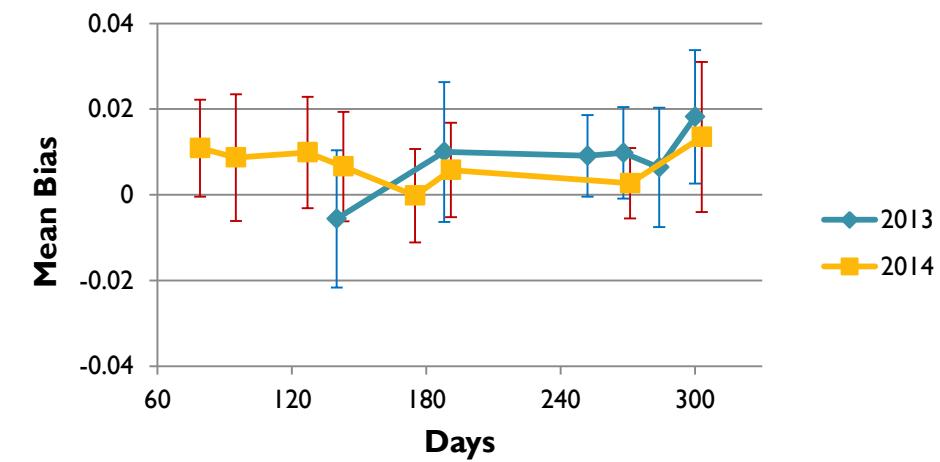
R: Landsat 5 TM  
Y: Landsat 7 ETM+  
G: Landsat 8 OLI



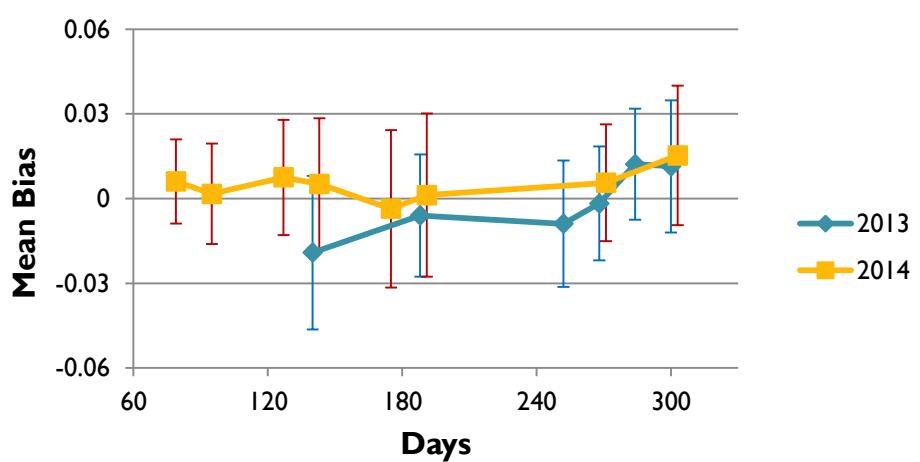
(a) Landsat 5/7 - MODIS, red



(b) Landsat 5/7 - MODIS, NIR

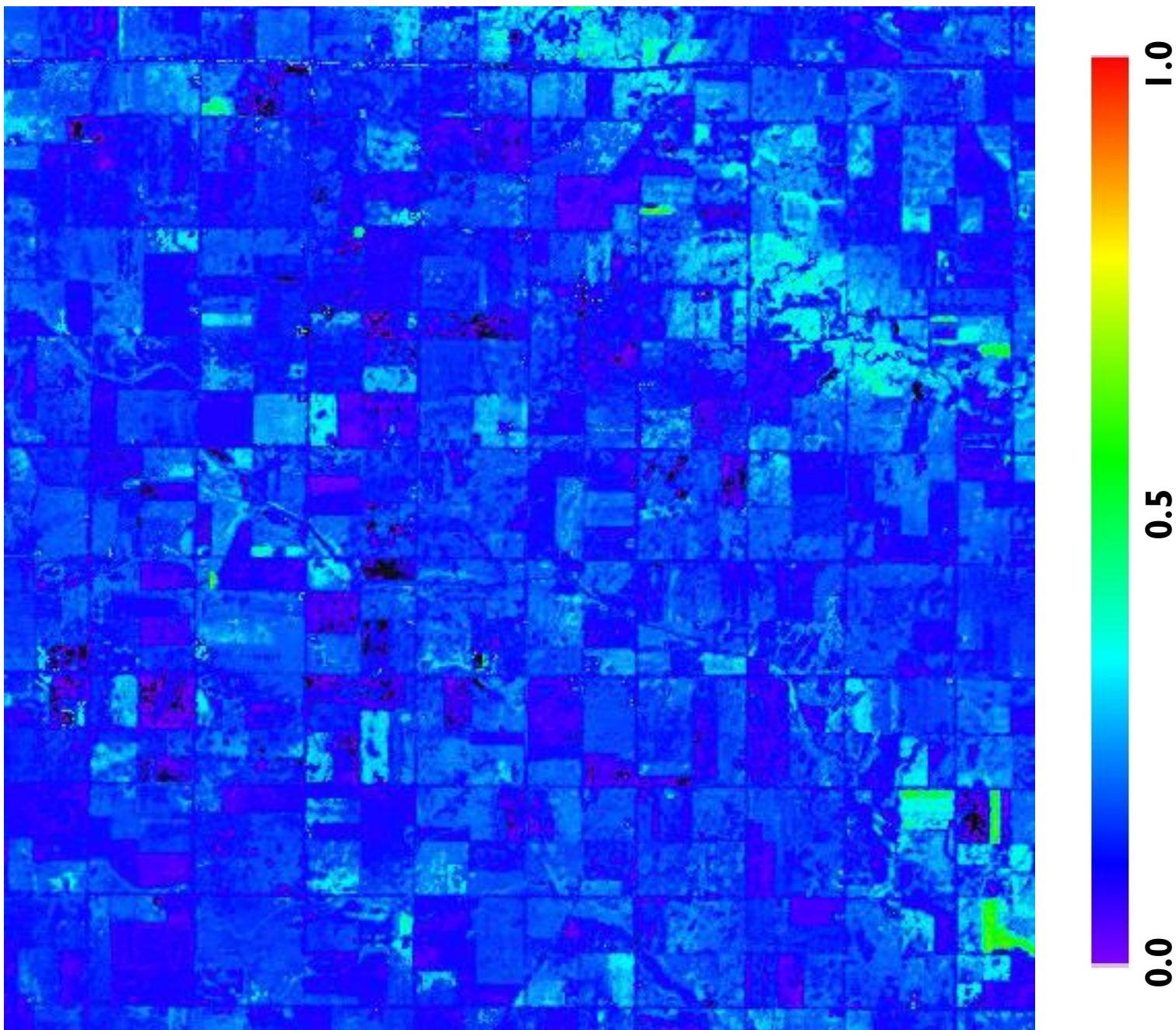


(c) Landsat 8 OLI - MODIS, red



(d) Landsat 8 OLI - MODIS, NIR

# Mapping Crop Progress and Yield at 30m Resolution



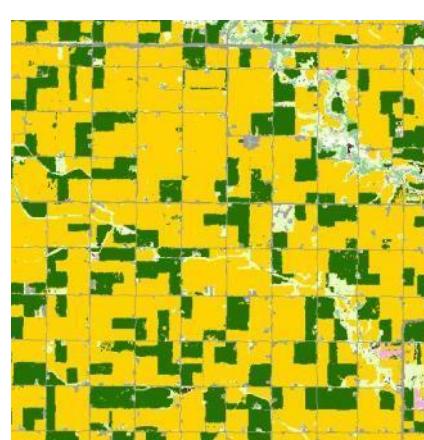
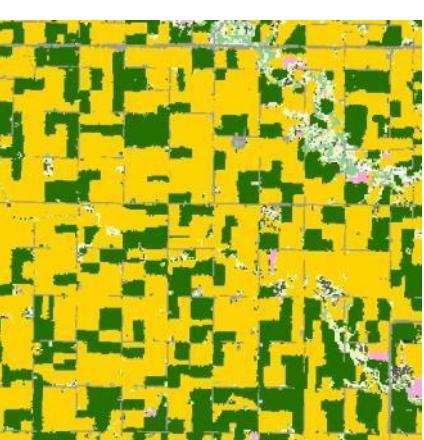
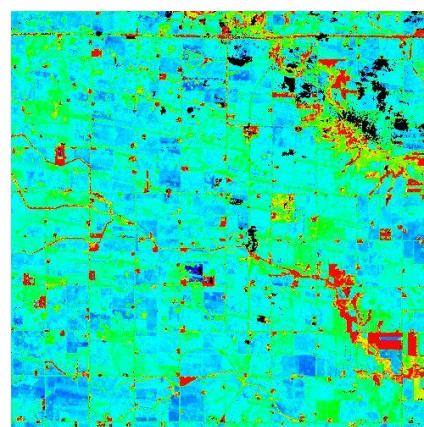
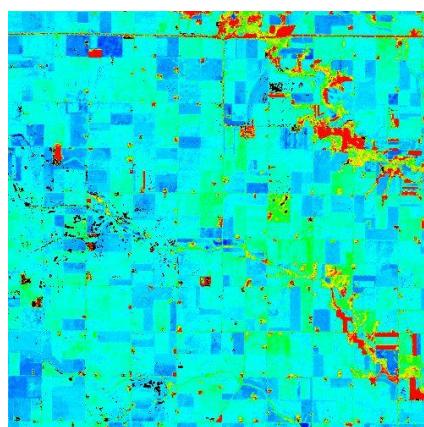
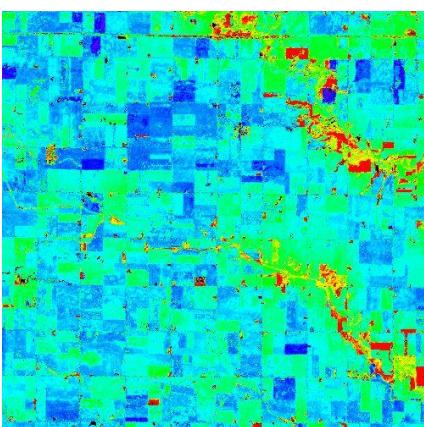
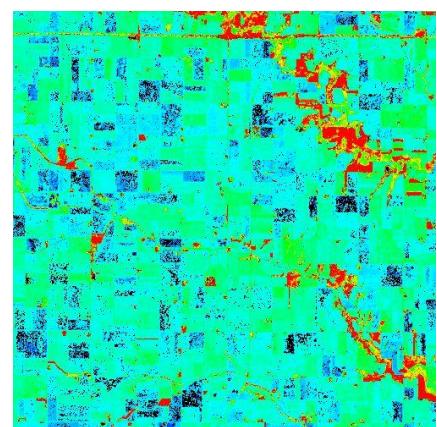
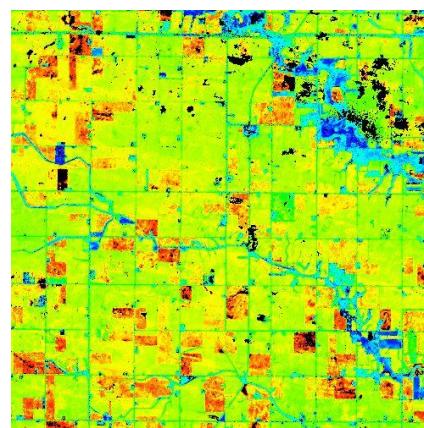
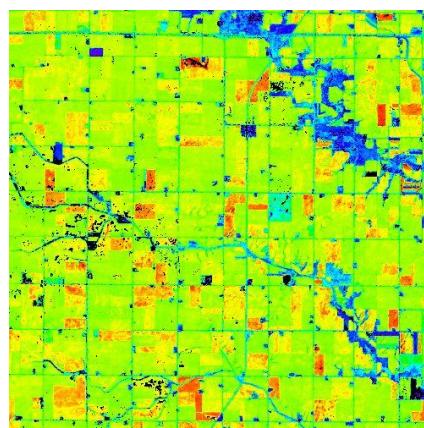
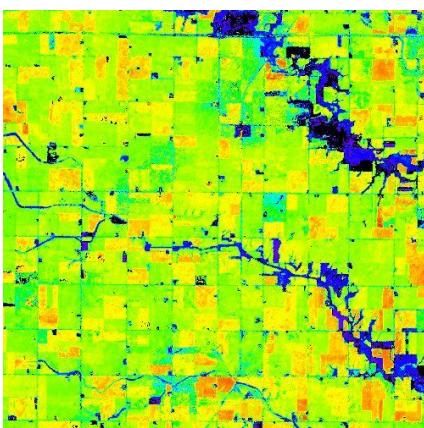
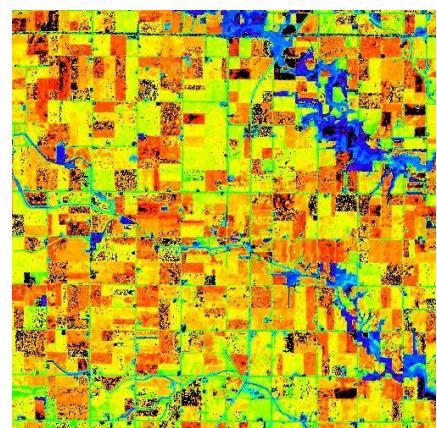
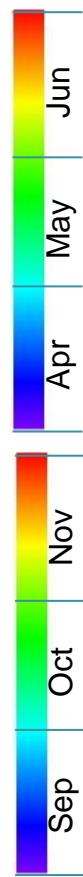
Smoothed (double logistic function) Daily NDVI, Apr. 1 – Nov. 1, 2011

2001

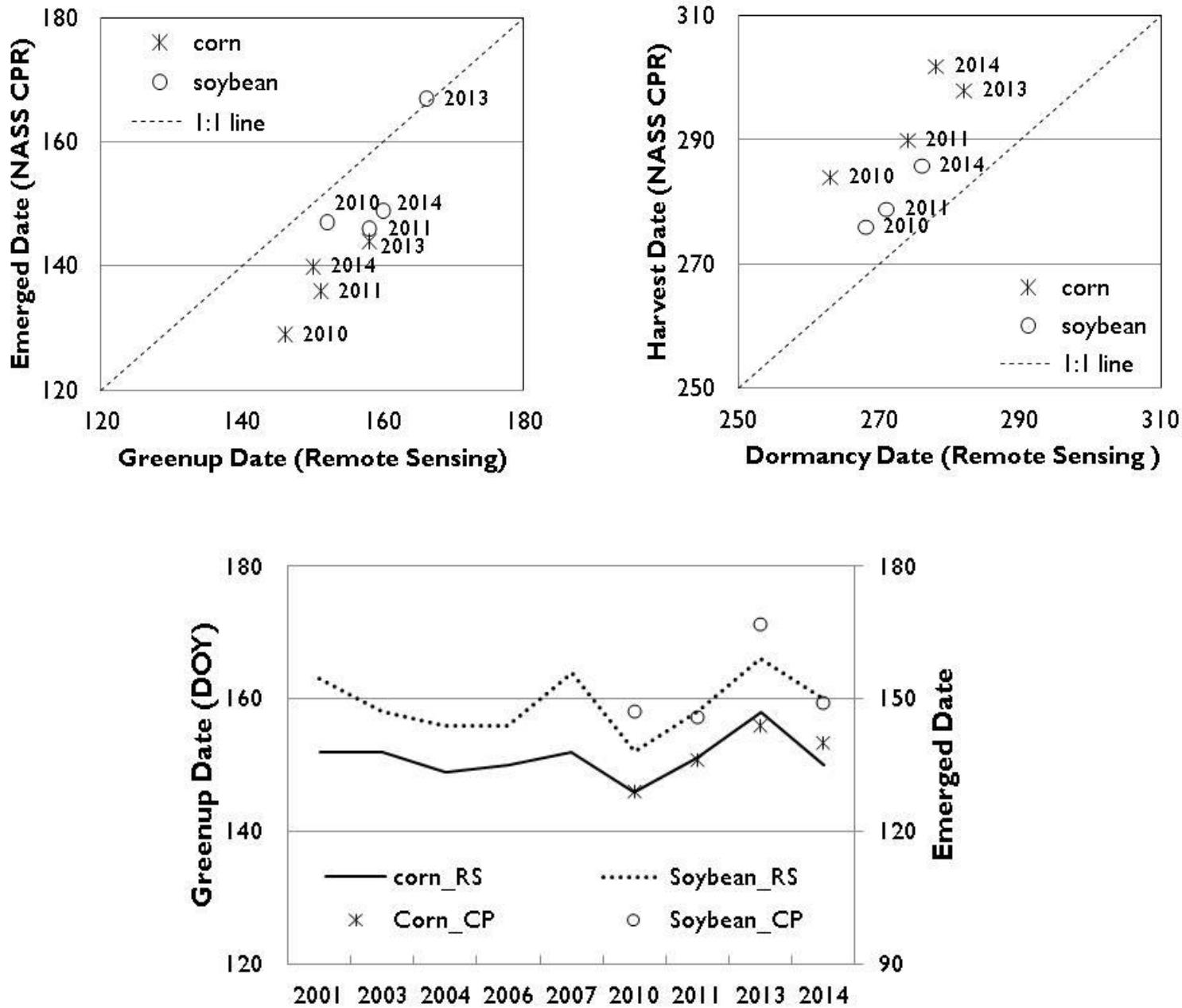
2006

2011

2014

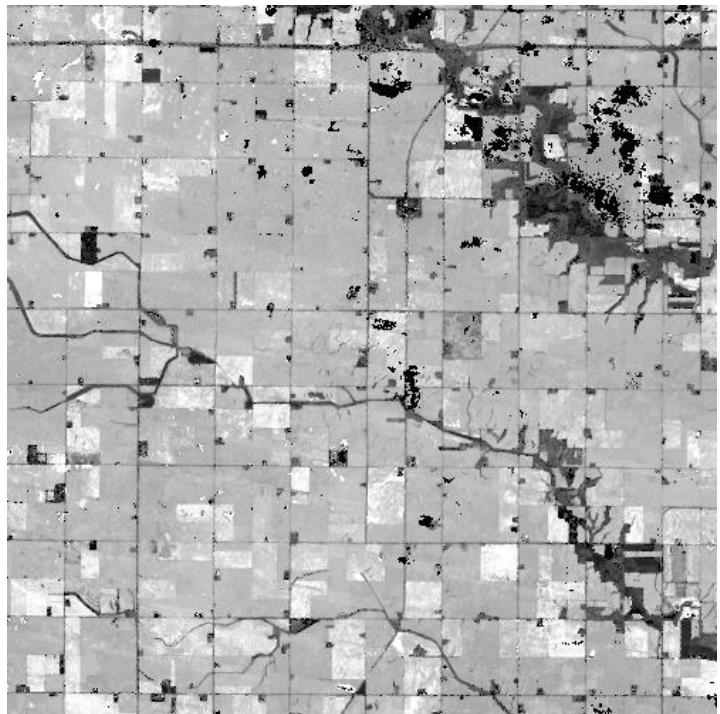


# Mapping Crop Progress and Yield at 30m Resolution

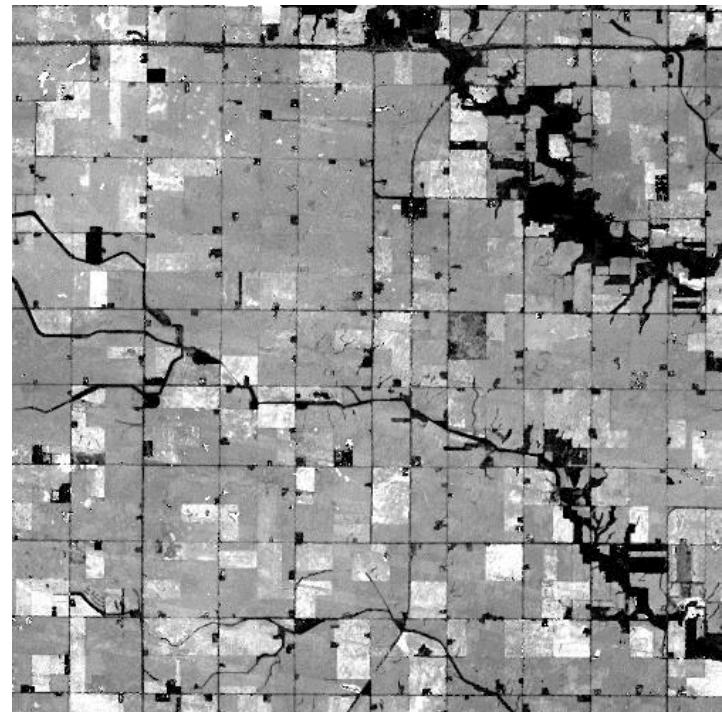
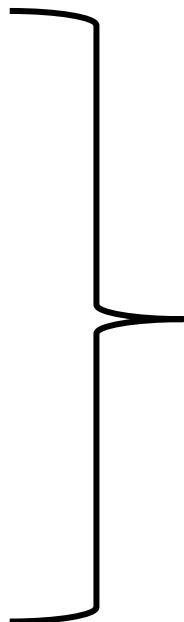
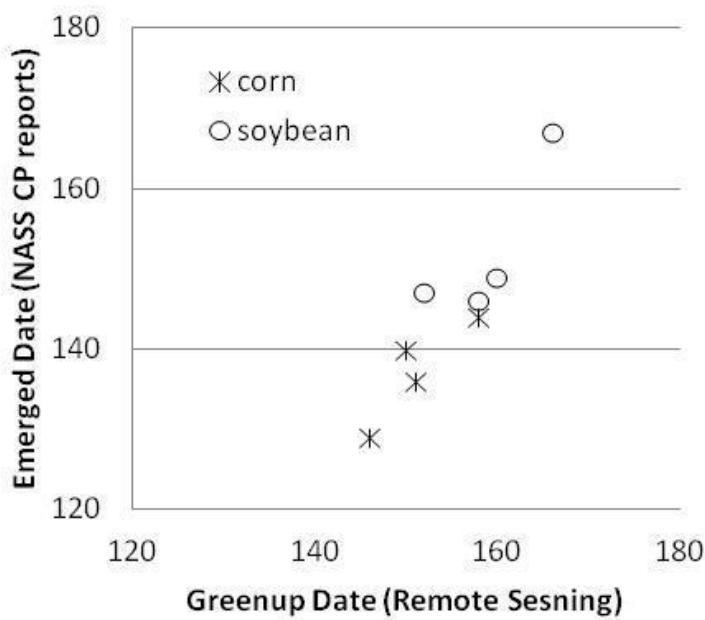


# Remote Sensing Phenology to Crop Growth Stages

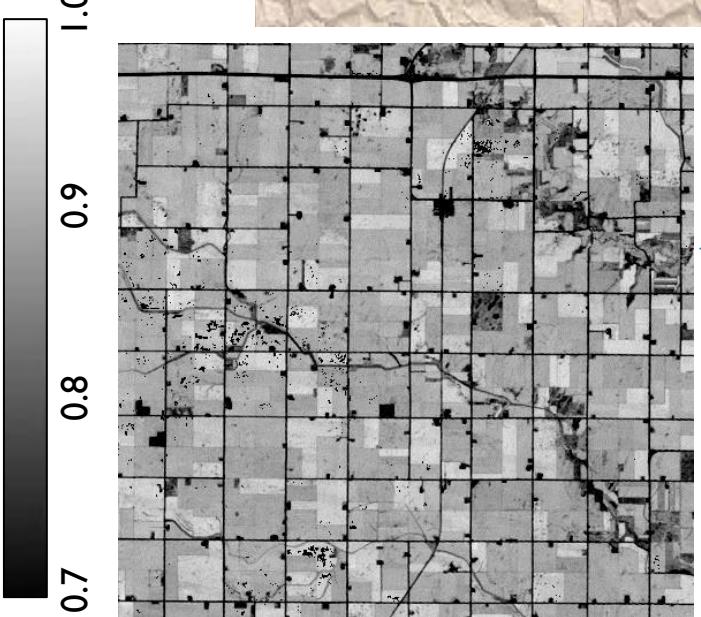
Greenup date



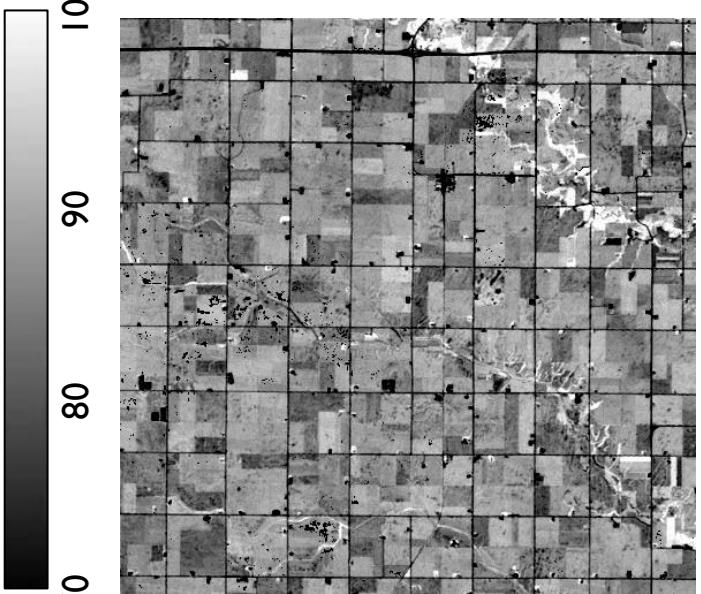
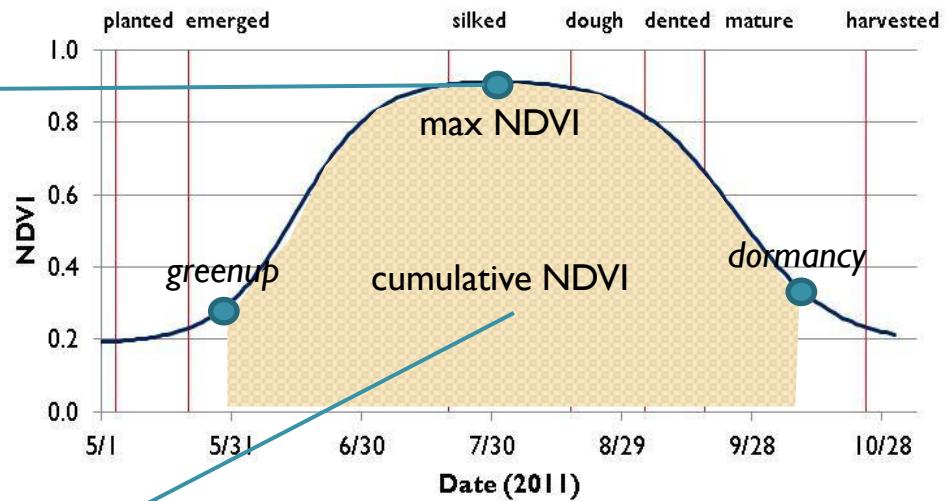
Relationship from previous years



$$Yield = \sum [PAR_i \times fPAR_i \times LUE_i(\varepsilon_{\max}, T, ET)] * HI$$



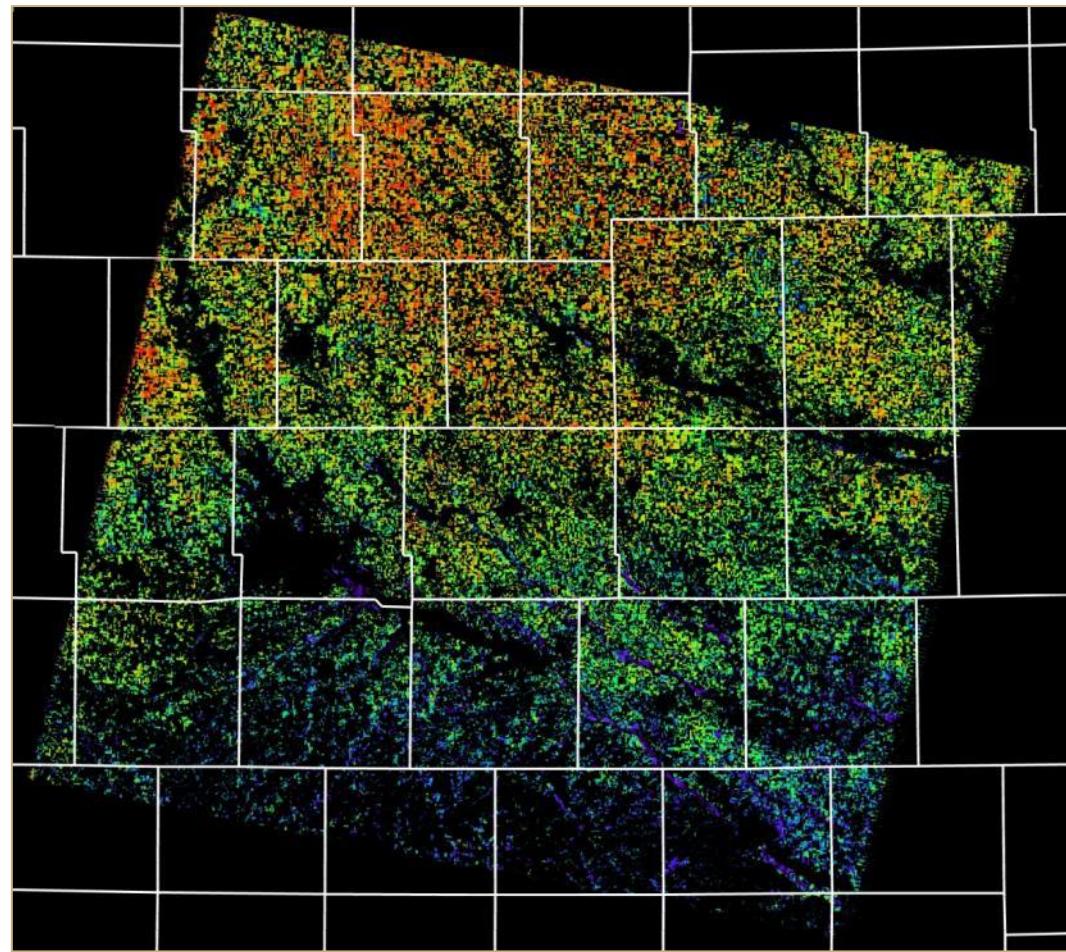
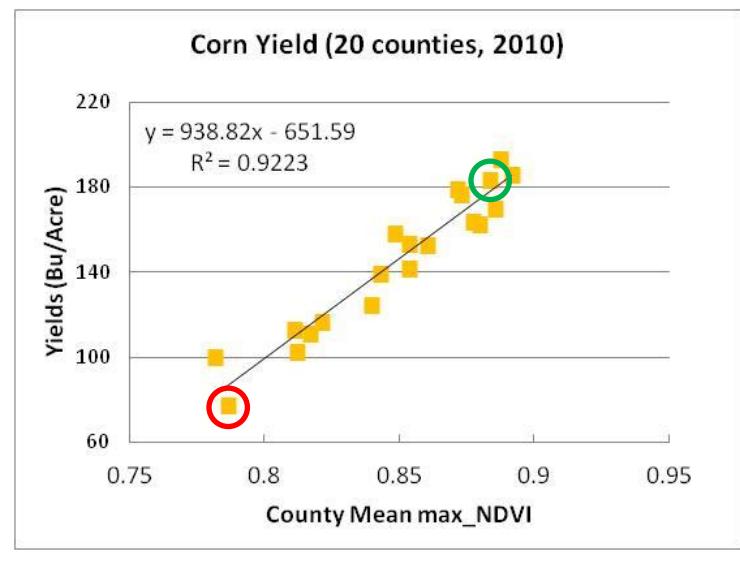
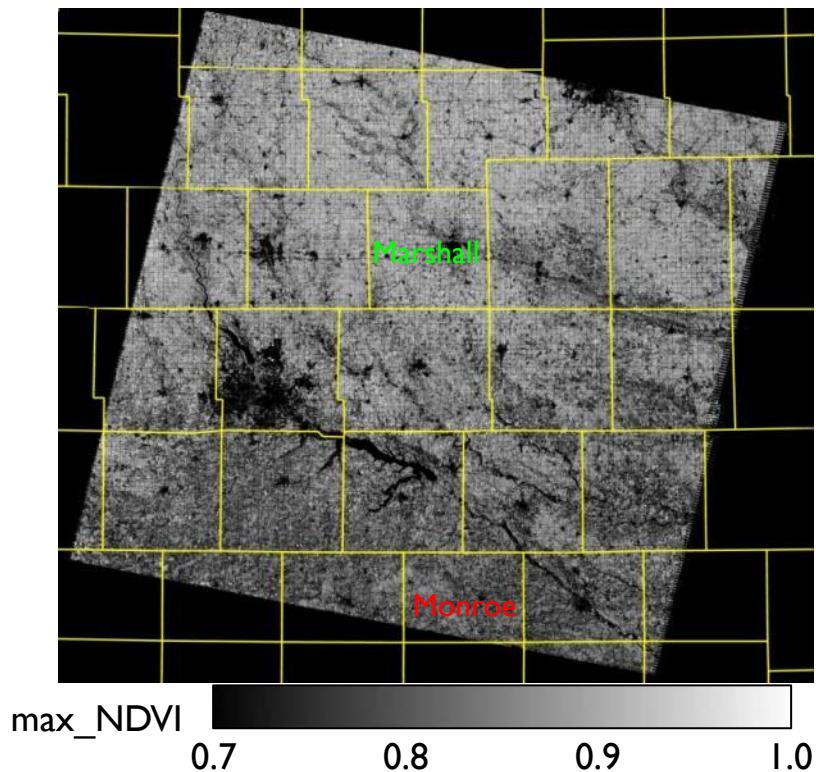
$$fPAR_i = f(NDVI_i)$$



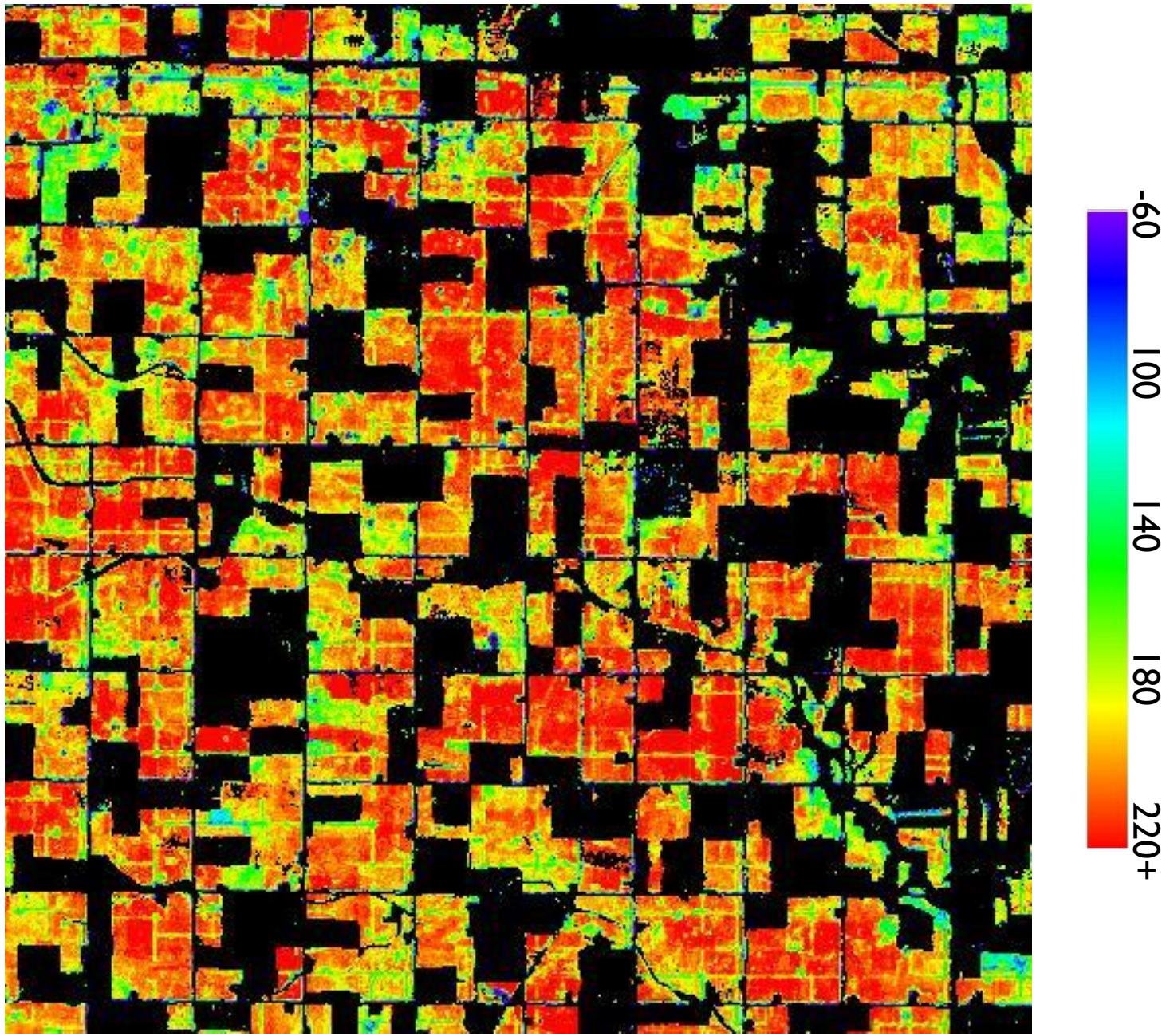
NASS  
CDL  
(2011)

- Corn
- Soybean
- Other Hay
- Developed
- D. Forest
- Grassland

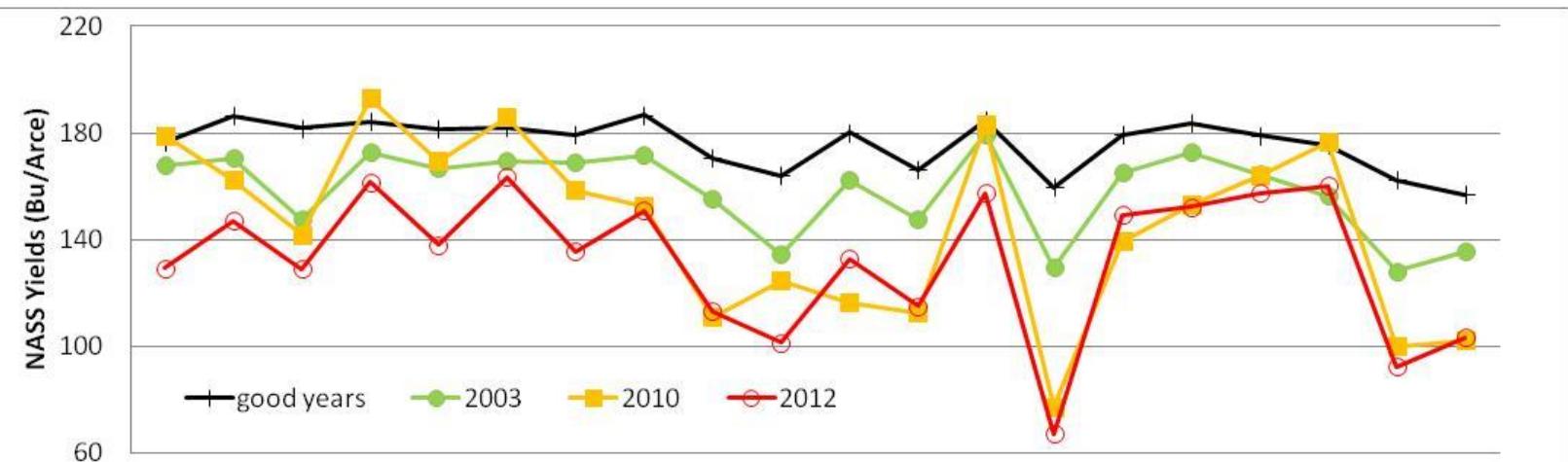
# Estimated Yields at Field Scale (corn, central Iowa, 2010)



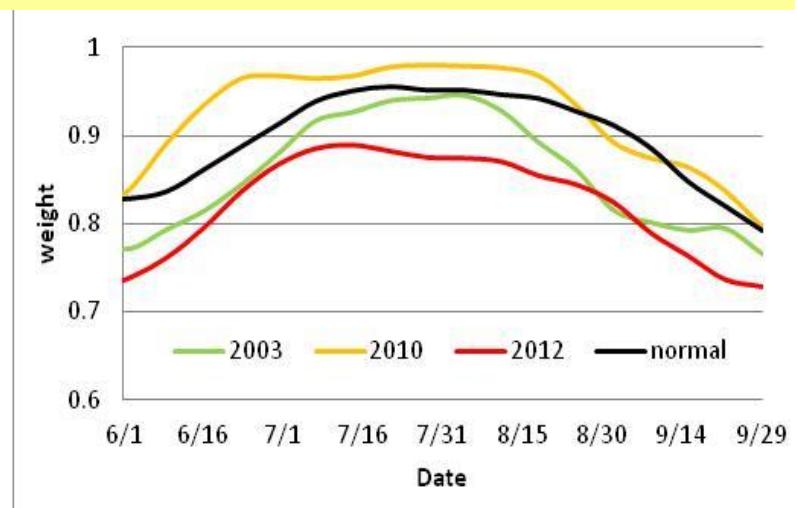
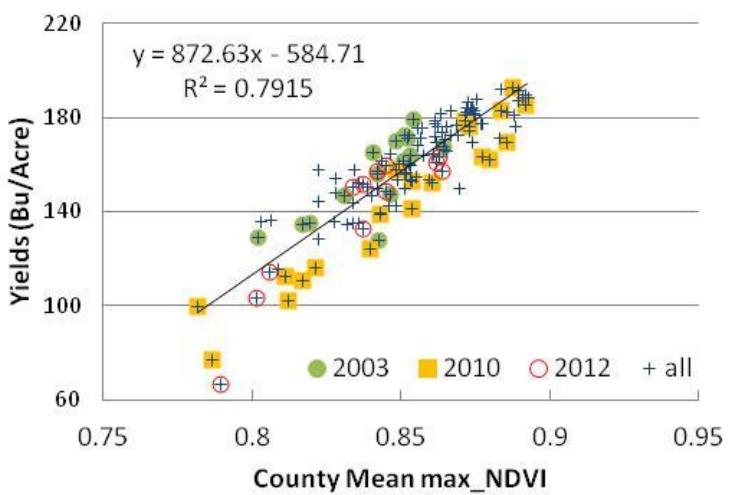
# 2010 Corn Yields (Bu/Acre) at South Fork



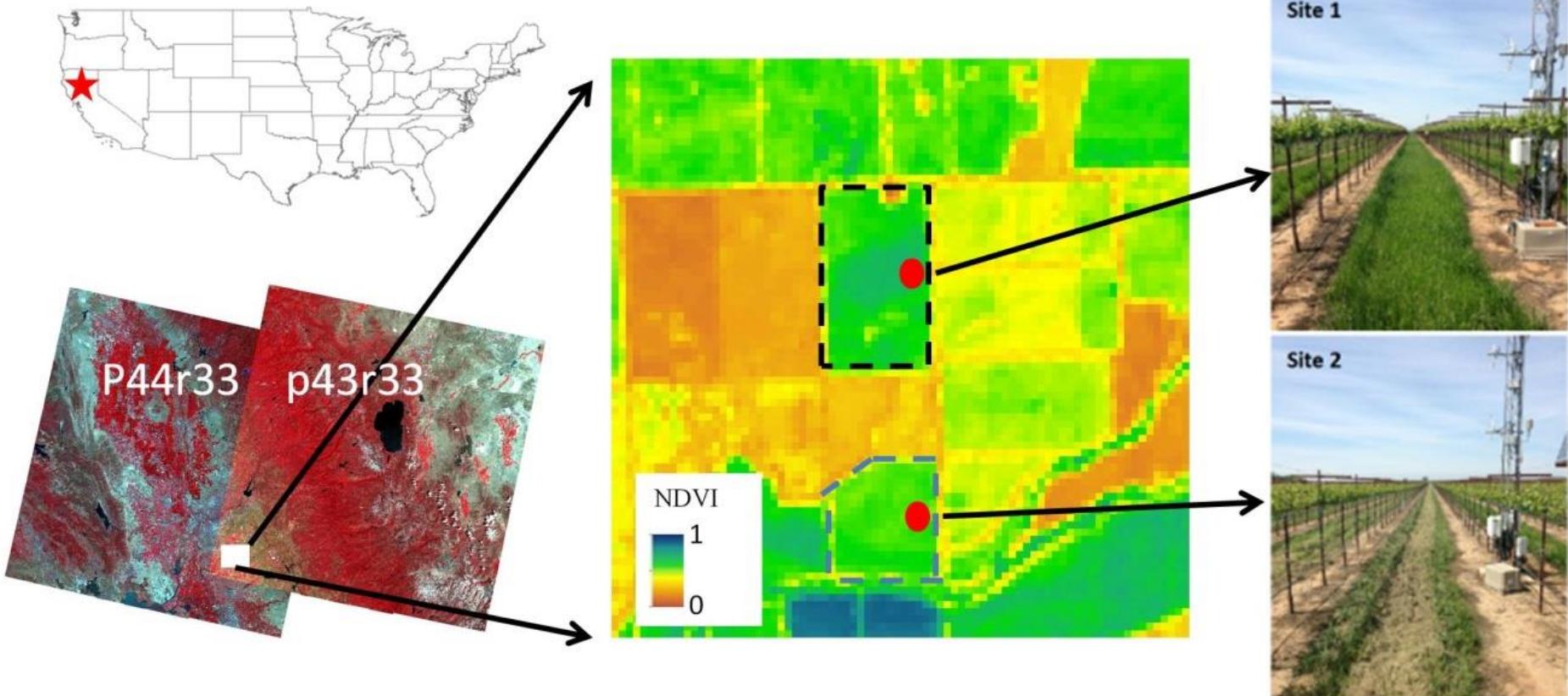
# Corn yields and NDVI metrics (county level)



$$Yield = \sum [PAR_i \times fPAR_i \times LUE_i(\varepsilon_{\max}, T, ET)] * HI$$



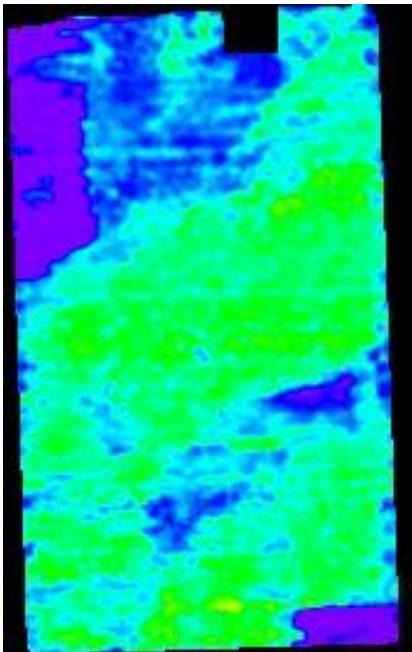
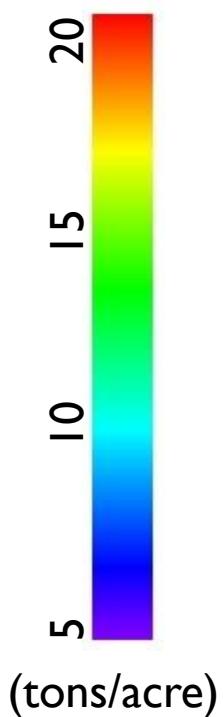
# Study Area II: Gallo Vineyards, Lodi CA



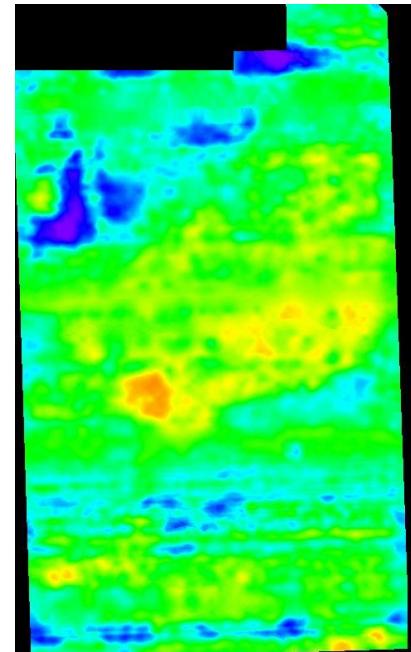
GRAPEX (Grape Remote sensing Atmospheric Profiling & Evapotranspiration eXperiment), 2013-2016 led by Bill Kustas



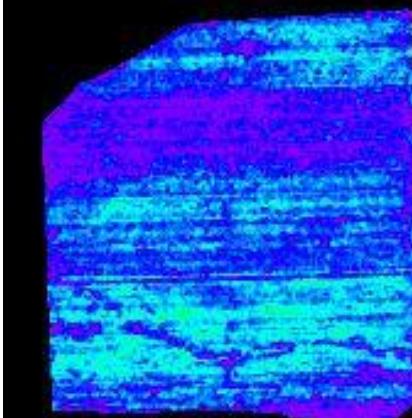
# Grape Yield Monitoring



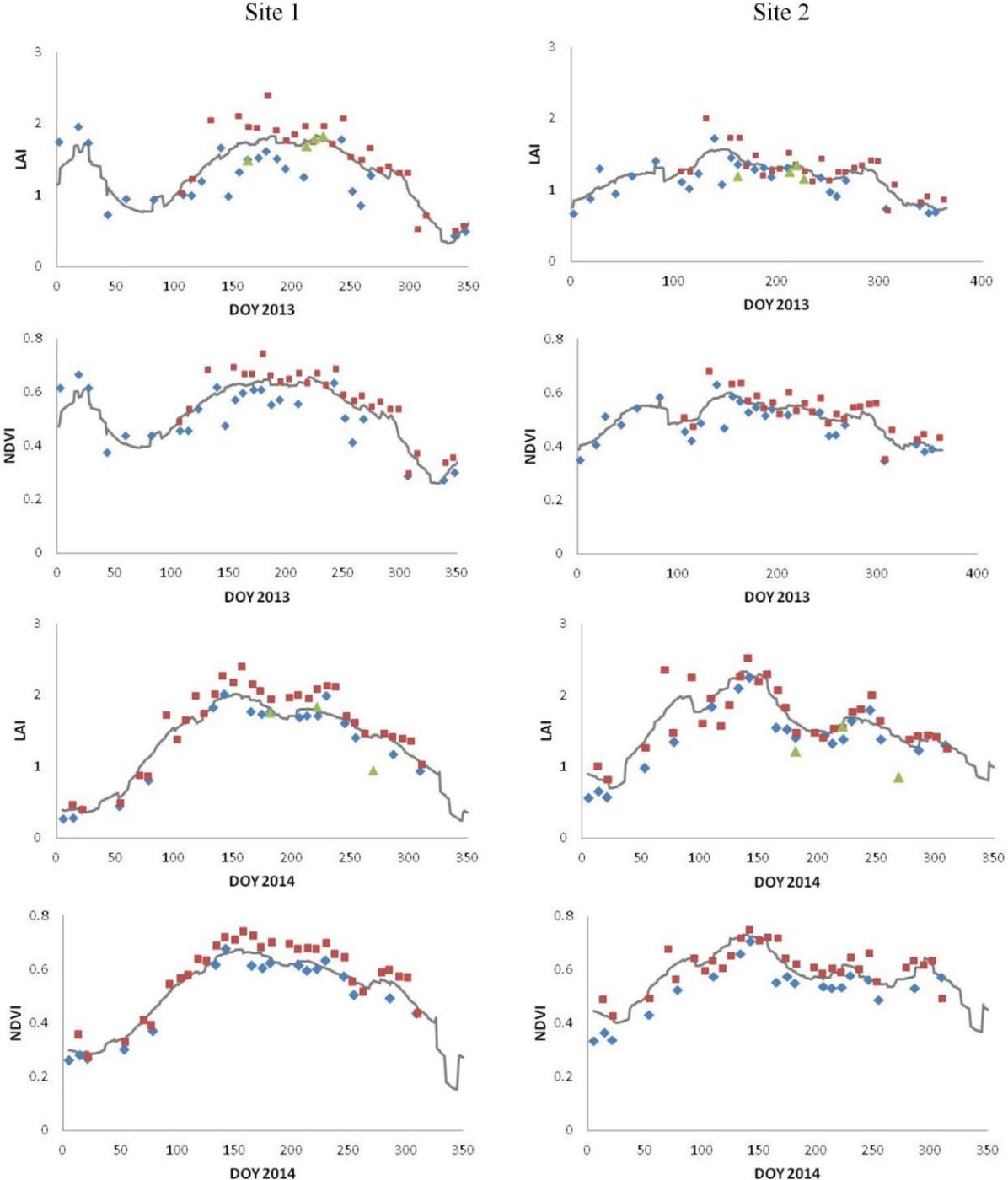
2013 (3m)



2014 (1m)



# Mapping Crop Progress and Yield at 30m Resolution



**L7 & L8  
Consistency  
LAI and NDVI**

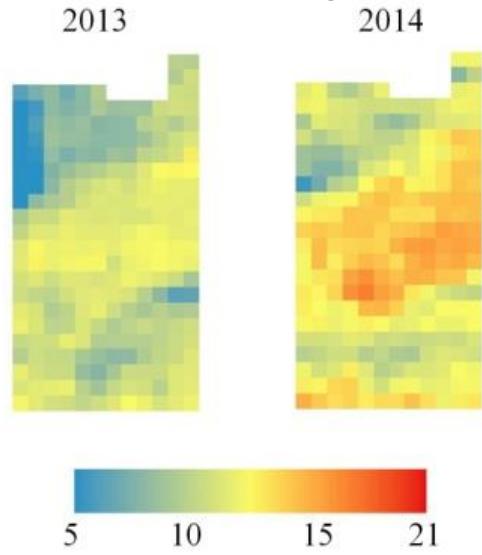
**Gallo Vineyards  
Lodi, CA**

◆ L7  
■ L8  
▲ obs  
— smoothed

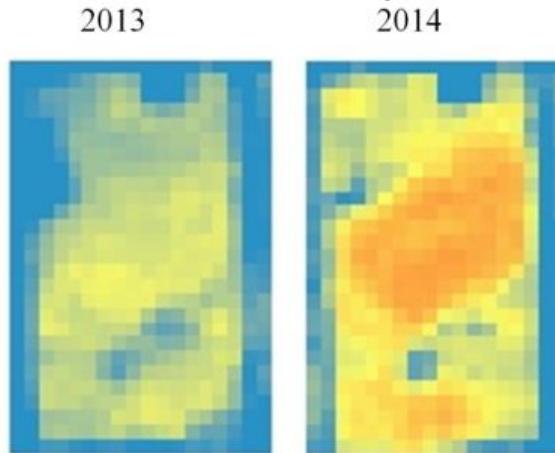
Landsat LAI  
retrieval  
approach see

Gao, F., et al.,  
2012, 2013

# Measured yield



# Predicted yield



## Yield prediction strategy:

Minimum and maximum NDVI and the corresponding yield was selected as samples from the best correlation day.

Year

Vineyard

bias (tons/acre)

RMSE  
(tons/acre)

Predicted  
production (tons)

Measured  
production  
(tons)

Relative error  
(%)

Year	Vineyard	bias (tons/acre)	RMSE (tons/acre)	Predicted production (tons)	Measured production (tons)	Relative error (%)
2013	North	-0.21	1.21	531	583	-8.9
2013	South	-0.46	1.07	247	279	-11.5
2014	North	0.71	1.67	792	720	10.3
2014	South	0.07	1.55	706	661	6.9

# Summary

- Crop progress monitoring and yield estimation require high temporal and high spatial resolution remote sensing data
  - 30m resolution is good enough for our study areas in Iowa and California. However, finer spatial resolution is needed for smaller fields in many countries.
  - Even using the daily Landsat-MODIS fused data, some areas and years were not be able to produce reliably crop phenology due to cloud contamination.
  - Data fusion technique can bridge close Landsat observations. More Landsat-like data are required to capture small changes.
- Consistent Landsat data is critical for inter- and intra-annual time-series analysis

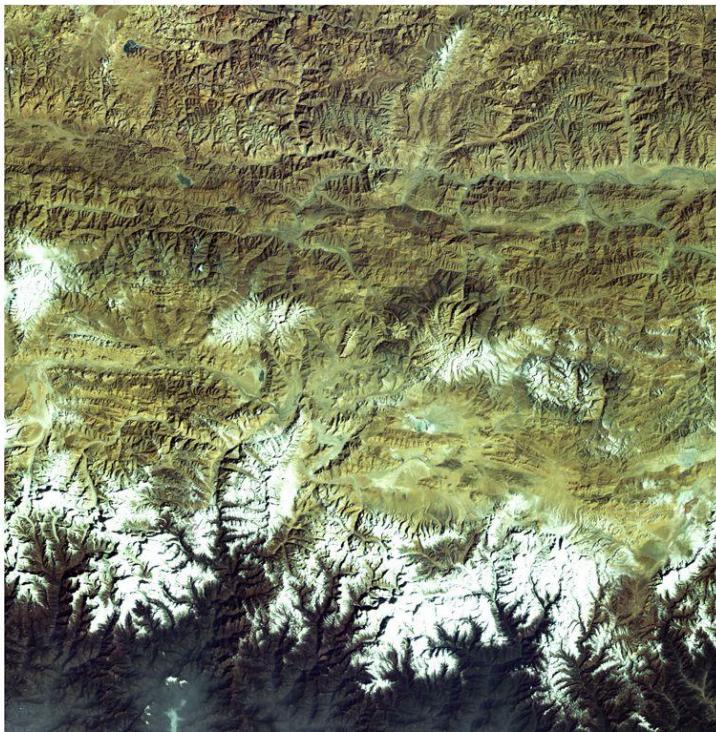
# GaoFen-4 Geostationary Satellite

China High-Resolution Earth Observation System (CHEOS)

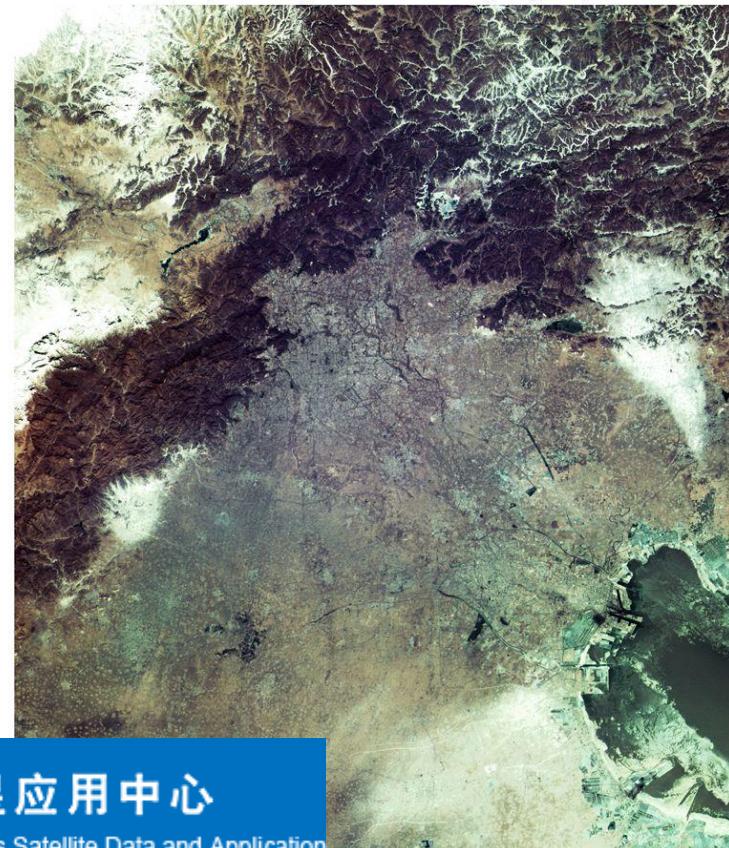
	Band	Bandwidth (μm)	Resolution (m)	Swath (km)	Revisit
VNIR	1	0.45~0.90	50	400	20s
	2	0.45~0.52			
	3	0.52~0.60			
	4	0.63~0.69			
	5	0.76~0.90			
MWIR	6	3.5~4.1	400		

Launched:  
12/29/2015  
Operation:  
6/13/2016

高分四号卫星珠穆朗玛影像



高分四号卫星北京影像



中国航天

中国资源卫星应用中心

China Centre For Resources Satellite Data and Application